

- 1 -

TITLE OF INVENTION

METHOD OF PERFORMING A PANORAMIC DEMONSTRATION  
OF LIQUID CRYSTAL PANEL IMAGE SIMULATION IN VIEW  
5 OF OBSERVER'S VIEWING ANGLE

FIELD OF THE INVENTION

10 The present invention relates to a  
method for performing a liquid crystal panel  
image simulation capable of predicting color,  
brightness, and contrast characteristics of an  
output image in view of a viewing angle of an  
observer who views a liquid crystal panel, and  
15 displaying the result of the image simulation.

More particularly, the present invention  
relates to a method for performing an image  
simulation in view of a viewing angle, and  
displaying the result of the image simulation.

20 With the increasing development of  
multimedia technologies, more people are using a  
liquid crystal displays (LCDs) which can be made  
small in size and light in weight such that they  
are applicable to notebook computers, personal  
25 digital assistants (PDAs), and hand-held phones,  
etc. However, the LCDs have different color  
implementation characteristics according to

- 2 -

viewing angles, such that they have a disadvantage in that a single image is differently viewed by a user's eye according to viewing angles. In order to solve the above-mentioned problem, many developers have conducted intensive research into a method for improving image output characteristics varying with a viewing angle.

In order to improve the image output characteristics varying with the viewing angle of the LCD, there have been widely used a variety of simulation software programs which calculate electric/optical characteristics of the LCD using a numerical analysis method, and predict a final output image of the LCD on the basis of the calculated result.

FIG. 1 is a conceptual diagram illustrating an image output method implemented by conventional LCD simulation software. Referring to Fig. 1, the conventional LCD display simulation software 10 acquires simulation result images 31 and 32 associated with individual viewing angles of an input image 20, and displays the acquired simulation result images 31 and 32 using an image result output module.

In the meantime, an LCD image viewed

- 3 -

with the naked eye of a user is determined to be  
an image based on a new coordinate system (i.e.,  
an eye coordinate system) on the basis of an eye  
position (i.e., a view point) of an observer who  
5 views an object, instead of an image based on a  
three-dimensional world coordinate system  
including x, y, and z axes. Moreover, there is  
no change in coordinate information contained in  
a world coordinate system associated with a  
10 screen, but the other coordinate information on  
the eye coordinate system varies with an  
observer's viewing angle. Therefore, although  
the LCD is fixed to a single position, the  
observer views different images according to the  
15 direction of his or her viewing angle.

Therefore, when the user views a  
simulation result image, the above-mentioned  
conventional image output method does not  
consider variation in shape according to the  
20 observer's viewing angle, and displays only an  
image formed by LCD image implementation  
characteristics varying with the variation in  
viewing angle.

FIG. 2 shows a difference between an  
25 image of the conventional image output scheme  
and the other image in which an eye-coordinate  
variation caused by the viewing angle is

- 4 -

considered. Referring to Fig. 2, if the observer views the LCD at a viewing angle (0,45), an LCD image viewed with the naked eye of the observer is determined to be an upper image 41 in which perspective is considered. However, the conventional image output scheme has a disadvantage in that it displays only an image formed by LCD image implementation characteristics in which a perspective variation based on the observer's viewing angle is not considered as shown in a lower image 42. The observer must view a current image after recognizing numerical viewing angle information of the current image, resulting in greater inconvenience of use.

In the case where the observer views simulation images based on viewing angles of not only the LCD but also other displays which must analyze viewing angle characteristics, the above-mentioned problems commonly occur in the above-mentioned LCD and other displays.

#### SUMMART OF THE INVENTION

Accordingly, it is an object of the present invention to provide a method for performing an image simulation according to an

- 5 -

observer's viewing angle, and providing the result of the image simulation in which the viewing angle information of the observer is considered.

5 It is another object of the present invention to provide a method for outputting an image simulation result such that an observer can conveniently analyze image implementation characteristics varying with a viewing angle of  
10 the observer.

In accordance with the present invention, the above and other objects can be accomplished by the provision of a method for displaying an image simulation result comprising the steps of:  
15 a) receiving information associated with a viewing angle of an observer; b) generating viewing transformation information using the viewing angle information; c) reading simulation image data to be displayed on a screen on the  
20 basis of the viewing angle; and d) projecting the read image on a projection plane perpendicular to the viewing angle, and performing a mapping process of the image on the projection plane.

25  
BRIEF DESCRIPTION OF THE DRAWINGS

- 6 -

Further feature of the present invention will become apparent from a description of a method for performing a panoramic demonstration of a liquid crystal panel image simulation according to observer's viewing angle taken in conjunction with the accompanying drawings of the preferred embodiment of the invention, which, however, should not be taken to be limitative to the invention, but are for explanation and understanding only.

In the drawing:

FIG. 1 is a conceptual diagram illustrating an image output scheme for providing an LCD image simulation result according to the conventional art;

FIG. 2 shows a difference between an image formed by a conventional image output scheme and the other image in which an eye-coordinate variation caused by the direction of the observer's viewing angle is considered;

FIG. 3 is a flow chart illustrating a method for displaying an image simulation result according to the present invention;

FIG. 4 exemplarily shows viewing-angle direction information and viewing transformation information according to an observer's viewing angle according to the present invention;

- 7 -

FIG. 5 shows an example in which coordinate information on an eye coordinate system is projected on a projection plane according to the present invention;

FIGS. 6~8 show methods for entering viewing angle information according to the present invention; and

FIG. 9 shows a plurality of mapping-image output examples according to the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

A method for outputting an image simulation result according to the present invention will be explained in detail with reference to FIGS. 3~9.

FIG. 3 is a flow chart illustrating a method for displaying an image simulation result according to the present invention. Referring to FIG. 3, a method for displaying an image simulation result according to the present invention receives information of a viewing angle desired by an observer at step S110, generates viewing transformation information associated with the received viewing angle using

- 8 -

the received viewing angle information at step S120. Subsequently, the above-mentioned method performs image calculation corresponding to a viewing angle of the observer or reads pre-calculated image data at step S130. An image to be displayed is projected on a plane perpendicular to the observer's viewing angle, and is mapped to the plane at step S140. And, the mapped image is displayed at step S150. It is determined whether the observer enters an input signal associated with another viewing-angle direction at step S160. If the observer enters another viewing angle information, a plurality of steps from step S110 in which viewing transformation information associated with the entered viewing angle information is generated, to step S160 in which it is determined whether yet another viewing angle information is entered, are repeated.

In accordance with a preferred embodiment of the present invention, step S120 during which viewing transformation information associated with a viewing angle upon receiving viewing angle information is generated, step S140 during which a calculated image to be displayed on a screen is projected on and is mapped to a plane perpendicular to the



- 9 -

observer's viewing angle in light of an  
observer's viewing angle, and step S150 during  
which the mapped image is displayed may use  
functions provided from open-source graphics  
libraries such as OpenGL and MESA, etc.

Viewing-angle information or viewing-  
angle direction information according to the  
present invention is indicative of a view-point  
coordinate for use in one or more world  
coordinate systems. Also, the viewing  
transformation information is indicative of  
information for converting a coordinate for use  
in a world coordinate system into a coordinate  
for use in an eye coordinate system.

FIG. 4 exemplarily shows viewing-angle  
direction information and viewing transformation  
information according to an observer's viewing  
angle according to the present invention.  
Referring to FIG. 4, the LCD screen 200 is  
positioned on a  $X_w Y_w$  plane contained in a world  
coordinate system including  $X_w, Y_w$ , and  $Z_w$  axes. An  
origin (0, 250) of the world coordinate system  
is positioned at the center of the LCD. In this  
case, the viewing-angle information is  
indicative of a spherical coordinate  $(\rho, \theta, \phi)$  or  
a rectangular coordinate  $(X_E, Y_E, Z_E)$  in  
association with a view point (E, 260) displayed

- 10 -

on the world coordinate system. In the spherical coordinate,  $\rho$  is indicative of a distance from the origin  $O(250)$  of the world coordinate system to a view point  $E(260)$ ,  $\theta$  is indicative of an angle formed between the  $X_w$  axis and a segment passing through a point  $E'(260)$  projected on the  $X_wY_w$  plane and the origin  $O(250)$ , and  $\phi$  is indicative of an angle formed between the  $Z_w$  axis and a vector from the origin  $O(250)$  to the view point  $E(260)$ .

In the meantime, the eye coordinate system includes  $X_e, Y_e$ , and  $Z_e$  axes, and uses the view point  $E(260)$  as the origin. Also, the  $Z_e$  axis is arranged in parallel to a vector from the view point  $E(260)$  to the origin  $(0)$  of the world coordinate system, and the  $X_eY_e$  plane is arranged in perpendicular to the  $Z_e$  axis.

In this case, a predetermined point  $(x_E, y_E, z_E)$  on the world coordinate system is converted into a point  $(x_e, y_e, z_e)$  by a viewing-transformation matrix shown in the following equation 1. The viewing-transformation information may be indicative of individual components of the viewing-transformation matrix.

[Equation 1]

- 11 -

$$\begin{bmatrix} x_e \\ y_e \\ z_e \\ 1 \end{bmatrix} = \begin{bmatrix} -\sin \theta & -\cos \phi \sin \theta & -\sin \phi \cos \theta & 0 \\ \cos \theta & -\cos \phi \sin \phi & -\sin \phi \sin \theta & 0 \\ 0 & \sin \phi & \cos \phi & 0 \\ 0 & 0 & \rho & 1 \end{bmatrix} \begin{bmatrix} x_E \\ y_E \\ z_E \\ 1 \end{bmatrix}$$

FIG. 5 shows an example in which coordinate information on an eye coordinate system is projected on a projection plane according to the present invention. Referring to Fig. 5, provided that a projection plane 300 is spaced apart from the view point E(260) by a vertical distance d(301), a horizontal width 302 of the projection plane is determined to be a value of 2W, and a vertical width 303 of the projection plane is determined to be a value of 2L, a coordinate on the eye coordinate system is determined to be coordinate information (X,Y) on the  $X_s Y_s$  projection plane including  $X_s$  and  $Y_s$  axes, and the coordinate information (X,Y) can be represented by the following equations 2 and 3:

[Equation 2]

$$X = d \frac{x_e}{z_e} + W$$

[Equation 3]

- 12 -

$$Y = d \frac{y_e}{z_e} + L$$

Therefore, according to the present invention, an observer can allow an LCD image  
400 varying with his or her viewing angle  
5 information to be displayed. In other words, image data differently calculated according to viewing angle information or pre-calculated image data is read out and is mapped to an LCD  
10 image in which perspective is considered, resulting in the implementation of a more realistic image varying with a viewing angle.

FIGS. 6~8 show methods for entering viewing angle information according to the  
15 present invention. As shown in FIG. 6, a user enters a spherical coordinate or a rectangular coordinate in association with one or more view points using a dialogue box 510 implemented by Windows program, such that the user can enter or  
20 correct viewing angle information. The user can also select pre-defined viewing angle information instead of the desired viewing angle information. As shown in FIG. 7, the user may determine the position of the view point on an  
25 additional coordinate system 520 using a mouse or keyboard, and may enter or correct the

- 13 -

position of the view point. As shown in FIG. 8,  
the user may click on or drag a desired  
coordinate on the projection plane 300 on which  
a mapped image is displayed, using a mouse, such  
5 that the user may enter or correct viewing angle  
information in real time, and at the same time  
may control the mapped image to be displayed.

In accordance with a preferred  
embodiment of the present invention, either one  
10 of information associated with an output image  
and viewing angle information 610 and their  
combination can be displayed on the projection  
plane 300 at the same time.

FIG. 9 shows a plurality of mapping-  
15 image output examples according to the present  
invention. Referring to FIG. 7, a plurality of  
divided projection planes are displayed at the  
same time, such that mapping result images  
associated with different viewing angles are  
20 shown at the same time.

As apparent from the above description,  
a method for displaying a simulation result  
image according to the present invention allows  
an image simulation result to be displayed in  
25 the form of an image viewed with the naked eye  
of an observer who views an LCD screen, such  
that it can analyze implementation

- 14 -

characteristics of a more realistic image. Also,  
the present invention allows the observer to  
enter a variety of viewing angles, and provides  
the observer with a variety of resultant images,  
5 and allows the observer to conveniently analyze  
image characteristics varying with a viewing  
angle.

Although the invention has been  
illustrated and described with respect to  
10 exemplary embodiments thereof, it should be  
understood by those skilled in the art that  
various other changes, omissions and additions  
may be made therein and thereto, without  
departing from the spirit and scope of the  
15 present invention.

Therefore, the present invention should  
not be understood as limited to the specific  
embodiment set forth above but to include all  
possible embodiments which can be embodied  
20 within a scope encompassed and equivalents  
thereof with respect to the feature set forth in  
the appended claims.